AUDITORY LOCALIZATION

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How do we tell where a sound is coming from?

- LOCALIZATION
- The ability to identify the direction and distance of a sound source outside the head

- LATERALIZATION
- Occurs when headphones are used, and the sound appears to come from within the head.

LOCALIZATION

- Complex perceptual process
- Sensory integration of a variety of cues
- Still no consensus on how these cues are weighted, the frequency range over which each is viable, the regions of auditory space where each is important, and relative accuracy of each.

Horizontal Localization (L vs R)

- Perceived by comparing the signal input between two ears
- Interaural time difference (ITD)
- Interaural phase difference
- Interaural level difference (ILD)

ITD

- Sounds arrive earlier at the ear closest to the source. The difference in arrival time=ITD
  - Dependant on speed of sound and size of head

  ITD = 0 for frontally incident sound

  ITD ~ 0.7 msec for 90° azimuth (maximum)

Interaural Phase Difference

- Coincident with the time delay (ITD)
- Varies systematically with source azimuth and wavelength due to distance from source and refraction around the head
- Useful for frequencies up to about 700 Hz.
- Sound envelope provides similar information for higher frequencies, but to a lesser degree
- Dominant cue for horizontal localization for frequencies up to 1500 Hz.

Interaural Level Difference (ILD)

- Due to head shadow effects
- Head and pinna defraction attenuates sound at far ear, while boosting the sound at near ear.
- Greatest for high frequency sounds
- Most pronounced for frequencies>1500Hz.
- About 20 dB at 6K, almost 0 at 200 Hz.

Horizontal localization poorest at 1500 Hz. Most precise at 800 Hz, esp. when source is directly in front of listener.

Horizontal Localization

- Low Frequencies / Timing Cues Dominate
- High Frequencies / Intensity Cues Dominate

Accurate horizontal localization is possible ONLY when the relevant acoustic cues are clearly audible in BOTH EARS

Vertical localization (Up/Down)

- Determined from pinna cues
- Listener's intimate knowledge of complex geometry of pinna helps pinpoint elevation
- For freq's above 5K
- Shoulder reflection causes changes in signal in 2-3 K range

Front/Back Localization

- Less understood
- Spectral balance = primary cue
  - Hi freq sounds boosted by pinna when they arrive from the front; attenuated when from behind

  MOST COMMON LOCALIZATION ERROR!

Reducing ambiguity

- Head movement
  - Feasible for sources up to 18’
  - Listener must be able to turn head, and source must be repeated or be continuous for sufficient time to allow multiple head orientations
  - Provides info re: front vs. back & distance
  - Cues are found in variance in ITD’s and ILD’s as listener moves head

Reducing ambiguity (con't)

- Non acoustic cues may also contribute
  - Visual cues
  - Source familiarity
- Comparison with stored patterns
  - Once head reaches final size and distance between ears, nothing will change these stored patterns except ear disease, trauma, or hearing changes
  - Can adapt to stable unilateral hearing loss, assuming sound remains audible on both sides.

Why is auditory localization important?

- Allows us to pinpoint a sound of interest
- Locate the position of another person
- Locate direction and distance of a moving sound source
- Allows us to quickly locate and attend to a speaker, esp. in multi-talker situations

Visual localization

- Just as accurate, but not nearly as efficient
- Not possible in low or reduced light situations, or when the source of the sound cannot be visualized

Effects of hearing loss on localization ablility

- Horizontal localization ability decreases with increasing low freq. hearing loss (below 1500 Hz)
- Sounds must be audible (at least 10 dB above threshold)
- Vertical localization ability decreases with increasing high freq. hearing loss

Unilateral hearing loss

- Severely disrupts horizontal localization ability
- Front to back localization remains intact (other studies dispute this)
- Vertical localization only slightly affected provided the other ear is adequate

Monaural localization

- May be possible, but not as accuarate as binaural localization
- Time delay between direct and pinna-reflected sound is the dominant cue for monaural localization
- Skill disrupted when pinna is taped flat, filled with putty, or bypassed with glass tubes

Repetitions plus head movement

- First occurrence of the sound random in terms of spatial orientation
- Listener makes effort to turn towards source for second repetition
- Third repetition with head at third (random) angle provides refined information

Conductive hearing loss

- Results in marked decrease in localization ability
  - As conductive component increases, the amount of B/C information becomes dominant where there is no interaural attenuation
  - Conductive hearing loss also causes disruption in phase information critical to localization

How do we measure localization ability?

- No standardized way to directly measure this ability
- Must be done through your own pinnae, therefore headphones tests (lateralization tasks) are *not* the same thing, even when head transfer functions are considered.

Effects of noise on localization

- Greatest decrease in accuracy found in judgment of front/back differences
- Up/down errors occur with less frequency
- Least influence on left/right judgments

- Accuracy decreases as S/N decreases

Source Azimuth in Noise Test (SAINT) Vermiglio 1999

- Listener sits in clock-like array of 12 speakers
- Task is to detect a signal (pistol shot, female vocalization) in quiet and in noise (helicopter noise, crowd noise) for a variety of presentation azimuths
- May be tested under headphones (no pinna cues for horizontal localization)

Hearing in Noise Test (HINT)

Soli and Nillson, 1994

- NOT a localization test
- May, however, provide indirect proof of binaural superiority as many subjects with unilateral loss will fail the portion of the HINT where noise is directed towards the good ear.

Establishing an audiometric standard

Suggested guidelines

- Applicants must have adequate and usable hearing in both ears, particularly for the all-important speech frequencies
- SRT MUST BE 25 dB OR BETTER IN EACH EAR WHEN TESTED UNDER HEADPHONES

Suggested guidelines, con’t

- Low frequency hearing loss in one or both ears averaging 50 dB at the frequencies of 500 and 1000 Hz. should be disqualifying *in and of itself* , regardless of performance on any other applicable audiometric tests

Suggested guidelines (con't)

- Conditions involving fluctuating hearing loss such as Meniere's disease should be disqualifying until such a point occurs that the hearing loss remains stable for at least 30 days. If the thresholds of 500, 1000, and 2000 Hz. differ by 25 dB or more in either ear, for two audiograms separated by at least 48 hours, hearing levels may be considered unstable.

Suggested guidelines (con’t)

- Unresolved or chronic conductive hearing loss in one or both ears, where air/bone gap exceeds an average of 25 dB at the frequencies 500 and 1000 Hz, should be disqualifying until or unless the condition can be successfully resolved through medical and/or surgical means

Use of hearing aids

- Hearing aids alter both time and intensity cues
- Digital processing can delay the sound by several msec., signal is further delayed as it travels through tubing, transducers, etc.
- Vented hearing aids allow listener to receive two different signals, which can cause ambiguity in time, phase, and intensity cues
- Coupling of device to ear eliminates critical pinna cues needed for vertical and front/back localization